COAL-MINE EXPLOSIONS AND COAL- AND METAL-MINE FIRES IN THE UNITED STATES IN 1949

By J. J. Forbes, W. J. Fene, and H. B. Humphrey

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J. J. Forbes,[1] W. J. Fene,[2] and H. B. Humphrey[3]

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1/ Chief, Health and Safety Division, Bureau of Mines, Washington, D. C.

2/ Assistant Chief, Health and Safety Division, Bureau of Mines, Washington, D. C.

3/ Mining engineer, Bureau of Mines, Washington, D. C.

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INTRODUCTION

Loss of life from coal-mine explosions in the United States in 1949 was the lowest in any year since before 1870. Although fatality reports from coal mines before 1910 were incomplete, the explosion fatalities from single disasters or individual States exceeded the 1949 total in each year as far back as 1870, when the records become fragmentary. Since 1890, the only other year in which fewer than 35 were killed was 1946, with a total of 32. Figure 1 shows the total yearly fatalities from explosions in all coal mines and those in anthracite mines alone since 1870. The fatalities in bituminous coal mines were not completely reported before 1910, but enough reports were issued by major coal-producing States to compile reasonably representative figures back to 1885. Any corrections would be additions to these totals.

The reason for the moderate total of 46 explosion fatalities in 1948 and the low total of 8 killed in 1949 is thought to be the serious and careful attention devoted to elimination of coal-mine explosion hazards after the disastrous explosions in 1947. The standards now being observed generally with respect to ventilation, rock-dusting, and inspections for gas are better than those found earlier in even the mines having the best reputations for safety. Exceptions are still numerous, but they are fewer, month by month, because of the pressure of Federal and State inspections and a changing conception of the hazards that should not be permitted underground. The prevailing precautions have not eliminated all ignitions of gas or dust, but they have limited propagation to small explosions and have prevented serious loss of life.

The number of ignitions (14) reported for the year was less than the average (24) for the 5 years 1944-48 and only half the average for the fiscal years 1929-44. Another favorable factor is that Bureau of Mines representatives were probably in closer contact with both small and large mines in nearly all coal-mining districts. Inspectors now assigned to individual districts are better able to keep informed on the happenings and the progress of safety in their districts. In 1948, one-fourth of the explosions were in mines that employed fewer than 10 men; this condition was duplicated in 1949.

In 1948, two coal-mine fires resulted in fatalities, one causing five deaths and another 2; a fire in a metal mine resulted in one death. In 1949, one fire in an anthracite mine killed 4 men. The death rate would have been much higher if protective measures had not been in effect in a number of larger mines where fires that started were controlled promptly and men were removed without casualty. The number of reported fires is increasing, and as it is improbable that more mine fires are occurring, it may be that more of the occurrences are reported.

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In 5 years, from 1944 through 1949, there were 136 explosions that caused 397 fatalities; in the 16 fiscal years from 1929 through 1944, 404 explosions resulted in 1,880 fatalities. In 1949, 8 fatalities resulted from explosions, compared with 46 during 1948 and 190 in 1947.

SUMMARY AND CONCLUSIONS

1. Improvement is evident in the reduction of explosion and fire hazards in coal mines, as shown by the records for 1949. The safeguards and attention accorded to these hazards since 1946 apparently have reduced the loss of life and damage to property, although the number of fires and ignitions has not been decreased. Deaths from explosions and fires in 1949 totaled 17, compared with 48 in 1948 and an average of 106 for the years 1944-47. The factors that contribute to explosions and fires are present in every mine, and constant vigilance on the part of everyone is necessary to prevent them from occurring.

2. The 14 explosions from electrical causes (a reduction in such explosions reported after 1945) indicate that this hazard is gradually being controlled. The low record for those years has also resulted from improved ventilation, as open-type electrical equipment is still widely used in gassy mines.

3. Of the 14 coal-mine explosions studied in 1949, 6 were in anthracite mines. The average number of explosions for the preceding 5 years was about 25. In 1948, 29 explosions were reported.

4. Loss of life in coal-mine explosions in 1949 was 8, compared with 46 in 1948 and an average of 78 in the 5 years from 1944 to 1948. The total of 8 deaths was the smallest since 1870, the first year for which records were kept.

5. Four minor explosions in 1949 resulted in 8 deaths, compared with 3 major explosions in 1948 that caused 32 deaths and 8 minor explosions that caused 14 deaths. One of the 1949 explosions was in a bituminous coal mine and three were in anthracite mines. Three of these were examples of explosions "that should not have happened," as the methane accumulations that were iginited were caused by interruptions of normal ventilation and neglect to examine the areas while that condition existed. The other resulted from unsafe use of black blasting powder.

In 1949, 10 explosions were reported in which no one was killed, although 24 were burned or otherwise injured.

6. Five explosions occurred in open-light mines; in 1948 the number was 7 and in 1947, 10. The average for 16 fiscal years, 1929-44, was 8.4. Nine explosions occurred in closed-light mines, compared with 22 in 1948 and an average of 16 for the preceding 4 years. During 1949, smoking was a possible cause of two explosions attributed to other causes where two or more possible igniting hazards were present. Of the two explosions caused by open lights, one was in a mine where gas entered when a machine cut into an old gas well, and one when gasoline was spilled and vaporized.

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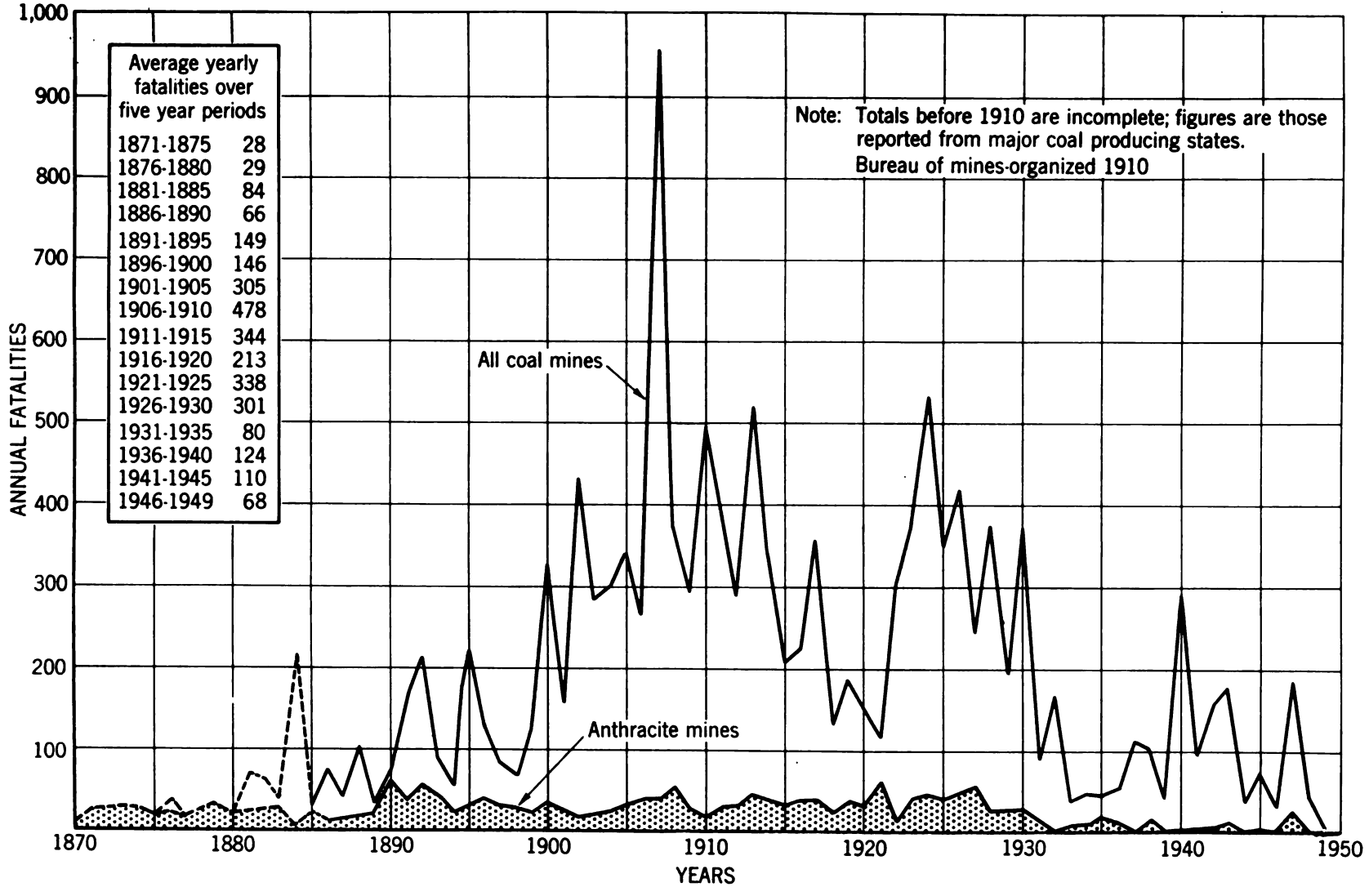

Figure 1. - Fatalities from gas and coal-dust explosions in all coal mines, 1870-1949.

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7. Four explosions, one of which caused 3 deaths, were of electrical origin, compared with 12 explosions and 29 deaths in 1948 and an average of 10.2 explosions and 35.2 deaths for the 5 years, 1944-48. Although more attention than formerly is given to safeguarding electrical installations and to the use of electrical equipment better suited to the hazards in coal mines, much of the equipment is still far from being reasonably safe from the risks of fire and explosion.

The use of nonpermissible equipment where gas and dust accumulations are not carefully controlled is a violation of accepted safe standards and ignores the possibility of an explosion. Use of electricity in the mines entails such hazards that only the safest available equipment, installations, and procedures should be accepted.

8. Six explosions, with 3 deaths, were caused by explosives during the fiscal year, compared with 11 explosions and 3 deaths in 1948 and an average of 7.8 explosions and 34 deaths annually for the 5 years 1944-48. The increase in the number of explosions from the use of explosives from 1944 to 1949 over the record of the preceding 16 years, and the heavy loss of life from them in 1945, 1946, and 1947, indicate that unsafe explosives and blasting practices have been prevalent in recent years, even though permissible explosives are being used in greater quantities and in more mines. These practices usually are found in small mines rather than in large ones, but explosions from this cause are not confined to the small "black powder" type of mine. Although the record was much improved over that of 1948, during which 11 explosions were caused by explosives, open shots and other dangerous practices caused explosions in three average or large mines in 1949; three "black-powder" explosions occurred in small mines. The continued use of black blasting powder or dynamite in coal mines will cause explosions, fires, and other accidents that result in death, injury, and destruction of property. Permissible explosives can cause explosions if used contrary to the permissible requirements, including maximum charge and minimum burden.

9. During 1949, nine explosions were initiated by ignition of gas and five by ignition of coal dust. In three of the mines where gas was ignited, ventilation was inadequate; in three others the ventilating current was interrupted or disturbed, in two other mines the gas accumulated in workings adjacent to active areas and was moved into the active workings; in the other ignition, a gas well through the coal bed was cut into by a mining machine. In six instances, inspection was inadequate, and the hazard of gas was ignored or forgotten. Seven of the gas ignitions were in mines recognized as gassy, the other two were in open-light mines; in one a gas well was cut into, as mentioned above, and in the other gasoline was spilled into a sump and ignited.

10. Of the five dust explosions, three were caused by blown-out shots or underburdened holes loaded with black blasting powder or dynamite. In another explosion, dust raised by a compressed-air line that was broken by blasting was ignited by an electric arc between the broken pipe and the trolley wire. Another explosion occurred when dust raised by blown-out shots was ignited by an arc from the firing line connected to the trolley wire. All of these explosions were primarily due to unsafe blasting practices.

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11. The 14 explosions during the year 1949 occurred in 4 States; those having fatal results occurred in only 2 of the coal-producing States. The anthracite region of Pennsylvania had 6 explosions with 5 deaths in 1949, compared with 4 explosions and 2 deaths in 1948. In the bituminous-coal fields of Pennsylvania, West Virginia, Virginia, Alabama, Tennessee, and Utah no fatalities from explosions occurred in 1949. In 1948, only Colorado, Ohio, Tennessee, Utah, and Virginia were without fatalities among the major coal-mining States.

12. The factors on which emphasis is laid by the explosions that occurred during the past year are the need for closer attention to thorough ventilation, closer inspection for gas that may enter from inactive workings, and elimination of the use of black blasting powder underground. The maintenance of adequate rock dusting is stressed both by the life-saving control that was accomplished by this means and by the loss of life where rock dusting was omitted or inadequate. Coal dust caused or was involved in five explosions; six of the remaining explosions were in anthracite mines, the coal dust of which is not explosive. Thus, in the 8 explosions in bituminous-coal mines, coal dust was ignited in 62 percent of them. There is ample evidence that rock dusting saved many lives and prevented considerable loss of property during the year.

13. In 1949, 30 coal-mine fires were reported, compared with 16 in 1948 and an average of 18 underground coal-mine fires annually for the 5-year period 1944-48. Four deaths were reported from coal-mine fires during the year. Eight metal-mine fires were reported, but no fatalities. In 1948, there were 16 coal-mine fires and 5 underground fires in metal mines; 8 fatalities were recorded, 7 in coal mines and 1 in a metal mine. One coal-mine fire cost 5 lives.

14. Of the 38 fires listed for the year, 17 were of electrical origin, 3 were started by open lights or flames, and 7 by explosives. Mine fires listed as miscellaneous in origin included spontaneous combustion, 8; surface fires spreading to the mine, 2; and belt friction, 1.

15. The decrease in serious coal-mine fires in 1946 and 1947 was not continued in 1948 and 1949. Although the record of the larger mines was good, there were numerous fires and some fatalities in smaller and irregularly operated mines. The absence of fires having serious consequences in the mines where protective measures are generally in effect upholds the conviction that fires can be eliminated as a menace to the point where disasters will be infrequent rather than an expected occurrence.

16. The outstanding cause of coal-mine fires, aside from spontaneous combustion, is overheating or short-circuiting of electrical conductors. Fires are frequently caused by damage to power circuits by roof falls or wrecks. Another common cause is the overheating of coiled power cables. If fires are not controlled quickly or men removed, some may be trapped or suffocated; derangements of ventilation may lead to explosions, and even if these things are avoided, much of the mine may have to be sealed and heavy expenditures made in extinguishing the fire and later reopening the area.

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The fire hazards present in most mines should be recognized, and practical measures should be taken to eliminate them. In addition, plans and equipment should be made ready to cope with fires that break out. Of first importance is a travelable means of exit for all men in the mine.

This circular follows those of earlier years, published as Information Circulars 6178, 6419, 6540, 6680, 6771, 6819, 6870, 6927, 6986, 7048, 7092, 7136, 7208, 7274, 7330, 7359, and 7456. The information given is that revealed by investigations made by the Health and Safety Division of the Bureau of Mines. The Bureau attempts to obtain the facts concerning every explosion and most of the fires in mines in the United States. Occasionally, some less destructive mine fires or explosions are not reported to the Bureau soon enough to permit investigation, but in most instances complete details are obtained of fires or explosions in which lives are lost or more than nominal property damage is done.

In recent years information has been relatively complete.

SUMMARY OF MINE EXPLOSIONS, BY STATES AND CAUSES

The essential information on 14 coal-mine explosions that occurred in four States and caused eight deaths during 1949 is given in table 1. The number of explosions in 1949 was 15 less than the 29 reported in 1948; the eight deaths in 1949 were 38 less than the total for 1948 and 182 less than for 1947.

There were no major explosion disasters in 1949. Three major explosions in 1948 resulted in 32 deaths, compared with 6 major explosions and 181 resulting deaths in 1947. Mine explosions that cause five or more fatalities are considered major disasters. In 1949, no fatalities resulted from 10 of the 14 recorded ignitions; in 1948, 18 of the 29 explosions caused no fatalities; of 23 reported explosions in 1947, 10 did not result in fatalities.

In 1948 a major disaster in Indiana, which caused 13 deaths, was initiated by the use of open-type electric equipment in a place where ventilation and inspection for gas was neglected. A major disaster in Alabama that resulted in the death of 11 persons was probably caused by the use of a damaged flame safety lamp in a place where ventilation was disturbed when a connection was being made between openings. In both of these major disasters the explosions were localized by rock dust, and only the men in the vicinity were endangered or affected. In Arkansas, a major disaster in which eight men were killed occurred when a gas accumulation was ignited by either an electric arc or by smoking. The explosion was violent and propagated throughout the mine by coal dust as rock dust that had been applied previously had not been maintained so as to be effective.

In 1949, six minor explosions in anthracite mines of Pennsylvania were reported, in three of which five deaths occurred. Two minor ignitions occurred in bituminous-coal mines of the State that caused no deaths. In Kentucky, one explosion took three lives; two others did not result in fatalities, although five men were injured.

Table 2 summarizes the causes of explosions during the fiscal years 1929 to 1944, inclusive, and for the calendar years 1944-1949, as compiled from the records of the Health and Safety Division of the Bureau of Mines.

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TABLE 1. - Summary of coal-mine explosions, by States and causes, 1949

State	Lighting used		Fatalities, by causes of ignition									
			Electricity		Open lights or smoking		Explosives		Miscellaneous		Total	
	Open	Closed	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
Arkansas	-	1	-	1	-	-	-	-	-	-	-	1
Kentucky	2	1	-	-	-	1	3	2	-	-	3	3
Pennsylvania	1	7	3	3	-	1	-	2	2	2	5	8
Virginia	2	-	-	-	-	-	-	2	-	-	-	2
Total	5	9	3	4	-	2	3	6	2	2	8	14

TABLE 2. - Summary of explosions, by causes, total of fiscal years 1929-44 and calendar years 1944-49

Years	Lighting used			Fatalities, by causes of ignition									
				Electricity		Open lights or smoking		Explosives		Miscellaneous		Total	
	Open	Closed	Unknown	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions
1929-44	135	241	27	1,067	179	398	135	318	58	95	31	1,878	403
Average, 16 years	8.4	15.1	1.7	66.7	11.2	24.9	8.4	19.9	3.6	5.9	1.9	117.4	25.2
1944	7	20		30	11	4	6	3	7	2	3	39	27
1945	6	23		40	14	3	5	16	9	23	1	82	29
1946	6	8		13	5	2	5	17	4	-	-	32	14
1947	10	13		64	9	5	5	121	8	-	1	190	23
1948	7	22		29	12	3	4	3	11	11	2	46	29
1949	5	9		3	4	-	2	3	6	2	2	8	14
6-year total	41	95		179	55	17	27	163	45	38	9	397	136
Average, 6 years	6.8	15.8		29.8	9.2	2.8	4.5	27.2	7.5	6.3	1.5	66.2	22.7

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In 1949, 3 men were killed by explosions ignited by electricity, compared with 29 in 1948 and an average of 66.8 for the period 1929-44. During 1949, 2 explosions were caused by open lights or smoking, compared with 4 in 1948 and an average of 8.4 for the 16 fiscal years 1929 to 1944. Explosions ignited by open lights or smoking resulted in no deaths in 1949, compared with 3 in 1948 and an average of 24.9 for the 16-year period 1929-44. Both ignitions by open lights were caused by abnormal conditions rather than accumulations of methane in the mines; in one, gas from a well was released, in the other, gasoline was spilled. In contrast, in 1948 four ignitions were caused by smoking in gassy mines. Smoking, permitted or practiced regardless of rules against it, was an outstanding violation of safety practices generally found in mines where explosions occurred in 1948. This violation was reported in 13 of the 22 mines in which closed lights were used. No evidence of smoking in violation of rules was reported in mines in which explosions occurred in 1949.

Six explosions, resulting in 3 deaths, were caused by unsafe blasting practices in 1949, compared with 11 explosions with 3 deaths in 1948 and 8 with 121 deaths in 1947. The average for the 16 years 1929-44 was 3.6 explosions and 19.9 deaths. In 1949, 4 of the explosions from this cause were in small open-light mines; in 1948, 7 of the 11 reported were in similar mines. In the others, in both years, the explosions were caused by the use of dynamite or other high explosive in unconfined or underburdened shots. In the small mines, the use of black blasting powder, shooting off the solid with little or no application of rock dust, was a combination that killed 3 and injured 16 men in 1949. In 1948, several men were killed or injured outside the mine portals by explosions that originated underground and were caused by black blasting powder.

Table 3 shows the record of explosions, by States, for the 16 fiscal years from 1929 to 1944 and for each calendar year from 1944 through 1949. In the earlier 16-year period, 403 explosions killed 1,878 mine workers, an average of 25.2 explosions and 117.4 men killed per year. The average number of explosions for the 5 years 1944-48 was 24.4 with 77.6 average yearly fatalities. In comparison, the record for 1949 of 14 ignitions and 8 deaths is a remarkable improvement. The record for 1948 of 29 ignitions with 46 killed was favorable only as a reduction from the 190 deaths in 23 ignitions in 1947. In the earlier 16-year period, Pennsylvania reported the greatest number of explosions - 108, with 317 killed. West Virginia reported 71 with 381 deaths; Ohio had 16 explosions with 209 killed; Kentucky, Alabama, Oklahoma, and Virginia had 16 to 41 explosions and 123 to 142 deaths. From January 1944 to December 1949, Pennsylvania reported 42 explosions with a total of 56 fatalities, Kentucky 24 explosions with 38 deaths, West Virginia 14 with 36 killed, and Illinois 7 explosions with a loss of 142 lives.

States in which no coal-mine explosions have occurred for an exceptionally long time are Wyoming, in which the last occurrence was in 1938, and Washington, which has not reported a fatality from an explosion since 1940. Coal-mining States that have not had fatalities from mine explosions in recent years are listed in table 4 which shows the year of the last explosion and the number killed.

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TABLE 3. - Record of explosions, by States, total fiscal years 1929-44 and for calendar years 1944-49

State	Fiscal years 1929-44		Average 16 years		Calendar years 1944		1945		1946		1947		1948		1949		Total 1944-49		Average 1944-49		
	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths	Ignitions	Deaths per ignition
Alabama	123	41	7.7	2.6	2	3	3	1	2	1		1	11	1			18	7	3.0	1.2	2.6-
Alaska	14	2	.9	.1																	
Arkansas	41	17	2.6	1.1	3	1							10	2	-	1	13	4	2.1+	.7-	3.2+
Colorado	59	15	3.7	.9	-	1		-	1	-	1						-	3	-	.5	-
Illinois	85	18	5.3	1.1	1	1	-	1	-	1	141	3	-	1			142	7	23.7-	1.2-	20.3+
Indiana	72	12	4.5	.8	1	2			-	1	11	3	13	2			25	8	4.2-	1.3+	3.1+
Kentucky	135	22	8.4	1.4	3	3	29	6	-	1	1	4	2	7	3	3	38	24	6.3+	4.0	1.6-
Maryland	1	1	.1	.1									3	1			3	1	.5	.2-	3.0
Montana	74	1	4.6	.1									-	1			-	1	-	.2-	-
New Mexico	22	4	1.4	.3	6	1											6	1	1.0	.2-	6.0
Ohio	209	16	12.4	1.0	-	1					1	1					1	2	.2-	.3+	.5
Oklahoma	142	21	8.9	1.3	1	1	9	1									10	2	1.7-	.3+	5.0
Pennsylvania	317	108	19.8	6.6	3	8	7	9	2	2	35	6	4	9	5	8	56	42	9.3+	7.0	1.3+
Tennessee	13	11	.8	.7			1	1									1	1	.2-	.2-	1.0
Utah	32	6	2.0	.4			31	3			-	1					31	4	5.2-	.7-	7.7+
Virginia	129	16	8.1	1.0	2	1	1	2	13	4	1	1	-	1	-	2	17	11	2.8+	1.8+	1.6-
Washington	21	19	1.3	1.2	-	1	-	1	-	2							-	4	-	.6+	-
West Virginia	381	71	23.8	4.4	17	3	1	4	15	1	-	2	3	4			36	14	6.0	2.3+	2.6-
Wyoming	8	2	.5	.1																	
Total	1,878	403	117.4	25.2	39	27	82	29	32	14	190	23	46	29	8	14	397	136	66.2-	22.7-	2.9+

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TABLE 4. - States without fatalities from explosions in recent years

State	Last fatal explosion		Number years to 1949
	Year	Number killed	
Alaska	1937	14	12
Wyoming	1938	5	11
Washington	1940	1	9
Colorado	1943	1	6
Montana	1943	74	6
New Mexico	1944	6	5
Oklahoma	1945	9	4
Tennessee	1945	1	4
Utah	1945	31	4

The record of explosions and fatalities in table 3 shows that the other coal-producing States had fatalities from mine explosions in 1947, 1948, or 1949. Coal-producing States not known to have had an explosion during the past 21 years are Iowa, Michigan, Missouri, North Dakota, and Texas.

By the totals of explosions and fatalities for the 16 fiscal years 1929-44, an average of 4.7 deaths resulted from each explosion. For the 6 calendar years 1944-49, the average number of deaths per explosion was 2.9. During the 6 years Illinois shows an average of 20.3 deaths per explosion, Utah 7.7, New Mexico 6, and Oklahoma 5. The averages of other States are lower, but as only a few years are covered in these averages they have little significance and are included only in the expectation that as additional years are added in annual revisions they will show comparative progress in explosion control.

CAUSES OF EXPLOSIONS

During the 16 fiscal years, 1929-44, shown in table 2, 403 explosions were studied, of which 179, or 44.4 percent, were caused by electricity. In the last 6 years, 55 of a total of 136 explosions, or 40.4 percent, were from this cause. Four such explosions occurred in 1949, 12 in 1948, and an average of 10.2 for the 5-year period 1944-48. During the earlier 16 years, open lights and smoking were given as the cause of 135 (33.5 percent) of the explosions recorded. These two causes were responsible for about 74 percent of the known explosions during those 16 years. In the 6 years 1944-49, 60.3 percent of the explosions were from these two causes, 40.4 percent from electricity, and 19.9 percent from open lights and smoking, indicating that most of the improvement has been in the hazards from smoking and open lights. Although great improvement in these respects is evident, smoking in gassy mines has been noted and has caused ignitions within the last 2 years. Means must be found to overcome the disregard of the dangers of smoking, and the indiscriminate use of open-type electrical equipment must be curtailed or the ventilating systems improved considerably if there is to be further reduction in the porcentage of explosions from those causes.

Although 11 explosions were caused by unsafe blasting practices in 1949, only 3 deaths resulted. During the 16 fiscal years 1929-44, 58 explosions

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(14.4 percent) were so caused, an average of 3.6 explosions a year. In the last 6 years this average has been 7.5, indicating that safe blasting procedures, such as are now standard practice, are not followed in many coal mines.

EXPLOSION FATALITIES, BY CAUSES

Table 2 shows that 1,878 were killed by explosions in the 16 fiscal years 1929-44 and that 397 were killed in the 6 years 1944-1949. Explosions of electrical origin caused 1,067 (56.8 percent) of the fatalities in the 16-year period and 179 (45.2 percent) in the last 6 years. In 1949, 3 deaths were from explosions of electrical origin, whereas the average for the preceding 5 years was 36. The hazard from electrical ignitions of gas and dust was not effectively controlled or reduced before 1949, and it remains to be seen whether the progress indicated by the record for 1949 will continue. Only the safest types of electrical equipment should be used in coal mines and then only with adequate maintenance and proper ventilation of the working place.

Three deaths were caused by explosions from open lights or smoking in 1948; none in 1949. This compares with an average of 24.9 deaths in the fiscal years 1929-44 and 3.4 for the 5 years 1944-48. Table 2 shows fewer explosions from these causes since 1944 than in the years 1929-44. Most of the explosions and fatalities of this class were chargeable to smoking in gassy mines. The number of mines in which open lights are used is dwindling rapidly, but the number in which men persist in smoking has been disturbingly large. Both of these sources of ignition (open lights and smoking) should be eliminated from coal mines; they are in no way essential to the production of coal and are remnants of outmoded and dangerous practices.

Explosions caused by unsafe use of explosives resulted in 3 deaths in 1949 and a total of 163 for the last 6 years. A total of 318 deaths is shown from this cause for the 16 fiscal years 1929-44, an average of 19.9 annually. The increase for the recent 6-year period is due to the tragic occurrence at the Centralia mine in Illinois, where 111 lives were lost in March 1947. The number of fatalities from this type of explosion varies greatly from year to year, but the recurrence of such explosions and the total of fatalities over a number of years are evidence that hazardous blasting methods are practiced in many coal mines. Even though permissible explosives and other precautions are used in more mines each year, the number of explosions and resultant fatalities have not decreased. An examination of the reports of such explosions in 1949 shows that all (4) in bituminous coal mines were from blown-out shots; in three of these, black blasting powder was used, and in the other, an arc from the firing line connected to the trolley wire ignited the dust cloud. In the two anthracite-mine explosions from this cause, dynamite was used in blasting in chutes. In one instance the explosives may have ignited gas, in the other an arc from the firing line was thought to have caused the ignition. Even permissible explosives have caused infrequent but disastrous explosions when fired with combustible stemming or in overburdened shots.

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CAUSES OF EXPLOSIONS OF ELECTRICAL ORIGIN

The types of electrical equipment and the number of ignitions attributed to each type during the fiscal years 1929-44 and the calendar years 1944-49 are shown in table 5. In the earlier 16 years at least 179 explosions were reported to be of electrical origin and caused 1,067 fatalities. In the last 6 years, 55 explosions originating from electric arcs caused 179 deaths, of which 4 explosions and 3 deaths occurred in 1949.

TABLE 5. - Electrical causes of explosions, fiscal years 1929-44, calendar years 1944-49

Type of equipment or device	1929 to 1944	1944	1945	1946	1947	1948	1949	Total ignitions, 1944-1949	Total killed 1948	Total killed 1949
Locomotive (nonpermissible)	47	3	5	2	1	3/5	-	16	5	-
Mining machine...	40	4	1	-	2	3	1	11	3	-
Drill (nonpermissible)	19	2	1	1	-	3/1	-	5	13	-
Cable or nip.....	7	-	3	2	2	-	-	7	-	-
Motor hoist, etc.	17	-	1	-	3/2	1	3/2	6	-	3
Wire or circuit..	17	-	2	-	-	1	1	4	-	-
Unclassified arc.	32	2	1	-	3/2	1	-	6	8	-
Total.....	1/2/179	11	14	5	9	12	4	55	29	3

1/2/ Explosions of possible electric origin not included under locomotive - 1, mining machine - 1, shot-firing circuits - 2.

3/ One or more charged to electricity but may have been due to smoking.

Locomotives and nonpermissible mining machines were the sources of about 50 percent of the explosions of electrical origin during the last 6 years. Although eight explosions (about 28 percent of those of electrical origin) were from locomotives or mining machines in 1948, only one was caused by such equipment in 1949. In that year, one was charged to a mining machine, one to wiring, and two to hoist motors or controls. The circumstances of these ignitions, as in nearly all other instances in recent years, reveal the serious consequences that must be expected from repeated disregard of well-established safety practices. The more important failures in caution were: (1) Failure to test for gas before electrical equipment is taken into working places in gassy mines, or failure to test during operation, and (2) failure to provide and maintain adequate, continuous ventilation where electrical equipment is operated.

As more mines are mechanized each year, it might be expected that the number of explosions initiated by electricity would increase. As this has not happened, it appears that some definite benefits are being shown as

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results of recent improvements in the observance of obvious safe practices, such as adequate ventilation, testing for gas, and restricting the use of nonpermissible electrical equipment. More careful observance of these precautions is necessary if the number of explosions initiated electrically in a year is to be reduced.

LIGHTING IN MINES WHERE EXPLOSIONS OCCURRED

Table 2 shows the methods of lighting used in mines where explosions occurred since 1929. In 16 fiscal years from 1929 through 1944, 403 explosions were reported, of which 135 (33.5%) were in open-light mines, 241 (59.8%) in closed-light mines, but the kind of lights was not reported for 27 (6.7%) mines. In the last 6 years, 1944-49, of the 136 ignitions reported, 41 (30.1%) were in open-light mines and 95 (69.9%) were in mines using closed lights exclusively. During the calendar year 1949, five ignitions occurred in open-light mines and nine in mines using closed lights; thus, no general trend is indicated. Fewer open-light mines are operated each year, and as the chances of an explosion where open lights and smoking are permitted are greater than in other mines, it is probable that this class of mines will continued to have a heavy share of the explosions in proportion to the number of mines involved. The ratio of explosions between the two types of mines may not change greatly until very few mines are left in the open-light class. Closed lights are used in most gassy mines, but in some not enough care is exercised to eliminate other sources of ignition, such as from dangerous blasting practices, use of nonpermissible electrical equipment, smoking, failure to maintain adequate ventilation, and vigilant testing for gas. In an open-light mine, gas may be a potential hazard even though the mine is considered nongassy. In 1949, three of the five explosions in open-light mines were coal-dust explosions caused by blasting with black blasting powder, one was an ignition of gas that escaped from an old gas well through the coal bed, and one was caused by ignition of gasoline fumes with an open light. Gas ignitions by open lights in small mines are no longer numerous, but they will not be eliminated as long as open lights are used.

EXPLOSIONS IN BITUMINOUS-COAL MINES

The trend of annual total fatalities resulting from gas and dust explosions in bituminous-coal mines of the United States during the calendar years 1906 to 1949 is shown in figure 2. The downward trend from 1907 to 1921 was reversed by the bad records of 1922-24. A declining trend occurred between 1924 and 1935, although in every other year a partial reversal of the downward trend occurred. Since 1935 the record has been erratic, with heavy fatalities in 1940 and lows of 33 deaths from explosions in 1944 and 30 in 1946. The reversal of the trend between 1924 and 1936 for each alternate year has been attributed to the salutary effect of mounting explosions and fatalities in one year causing redoubled effort to initiate preventive measures that are reflected favorably the following year. Such efforts were often relaxed after a year of good record in the number of explosions and fatalities. Since 1936, changes in mining methods and practices have been more rapid than before, and other factors have affected the trend. The large number of fatalities in 1947 indicates relaxed efforts in explosion-prevention measures. The low totals of 1948 and 1949 indicate effective measures that eliminated

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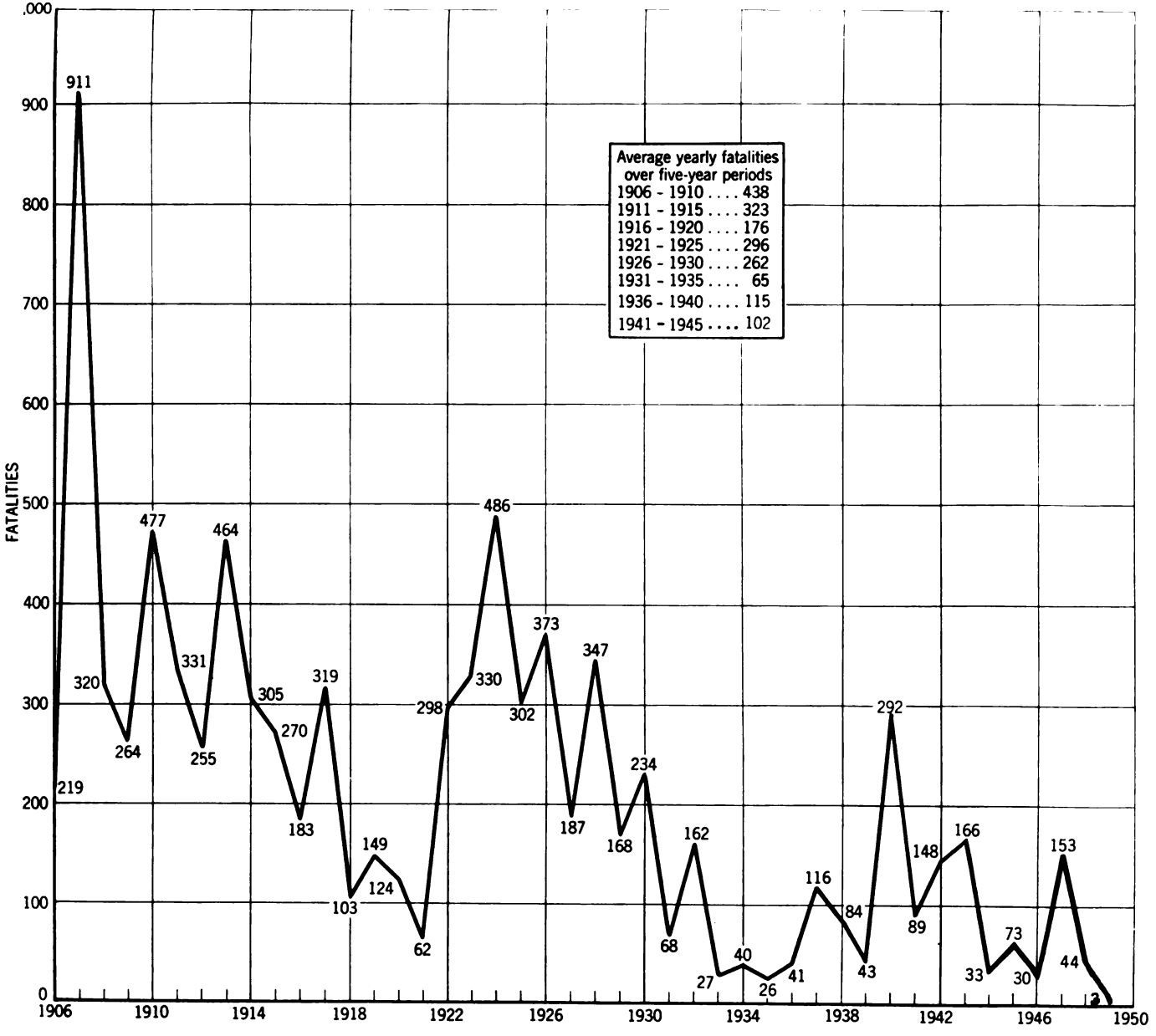

Figure 2. - Fatalities from gas and coal-dust explosions in bituminous coal mines.

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occurrences of explosions. Although the potential elements of coal-mine explosions - gas, dust, and an igniting spark - cannot be eliminated, they can be controlled and prevented from combining to produce an explosion.

There is less excuse for the occurrence of explosions than for any other type of mine accident. Means of prevention are well known, but because preventive means are not adopted explosions occur.

The average yearly fatalities from explosions are shown in figure 2 by 5-year periods from 1906-10 to 1941-45. The appalling average of 438 for the early years 1906-10 was reduced to 323 in the 1911-15 period and to 176 in the next 5 years. An increase to a yearly average of 296 for the period 1921-25 was followed by a drop to 262 and to 65 in the next two 5-year periods. In the two 5-year periods between 1936 and 1945, the averages were 115 and 102, respectively. These averages indicate tha the normal average fatalities from explosions would be about 100 a year, but the experience of the best years, 1933-36, 1939, 1944, 1945, 1946, 1948 and 1949 shows that a total of less than 50 per year has been recorded.

Such records can be reduced when a majority of the mine operators, mine workmen, and officials who are responsible for enforcement of mine safety laws adopt a firm attitude that explosion hazards will not be permitted in coal mines. Regulations of safe practices necessary for explosion prevention cannot be put into effect by any single group mentioned, but the desired result can be attained by cooperation and agreement. The primary step must be acceptance by all concerned of the concept that mine explosions are not a "trade risk," and that rigid preventive measures are practicable and desirable.

The hazards that contributed to explosions in the past year were (1) failure to provide and maintain continuous ventilation, including movement of gas accumulations from unventilated areas into working sections, 6 instances; (2) failure to test for gas before and while working in haulageways, face regions, or areas adjacent to where methane was known to be liberated, 6 instances; (3) use of open-type electric equipment without providing constant, adequate ventilation to prevent accumulation of explosive mixtures, 3 instances; (4) unsafe methods of blasting, including the use of nonpermissible explosives, 6 instances; (5) smoking in mines or use of open lights, 2 instances; (6) damaged or improperly adjusted flame safety lamps, 2 instances; and (7) inadequate rock-dusting, permitting propagation of an explosion, 3 instances.

All of the foregoing unsafe practices have been listed for several years in prior similar reviews as being causes of explosions in those years. In past years, failure to rock-dust adequately has permitted many explosions to develop into major disasters. Present indications are that the accepted standards of rock-dusting are being adhered to, which is preventing widespread explosions and saving lives. Disturbing factors are: (1) Ventilation is not closely controlled, especially where connections are being made; (2) tests for gas are not made before electrical equipment is operated; (3) flame safety lamps are not examined carefully enough to detect defects. Better practices should be instituted to avoid these shortcomings. The use of unsafe explosives - black blasting powder and dynamite - occurs mainly in small bituminous-coal mines and in anthracite mines, and the hazards are more serious than is generally thought.

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Smoking and the use of open lights should be condemned and outlawed.

MINE FIRES

During 1949, the Bureau of Mines received reports of 30 coal-mine fires and 8 metal-mine fires. Four deaths were charged to one fire in a coal mine, but none to those in metal mines. The coal-mine fire that caused fatalities was initiated by damaged power cables in a slope. In 1948, one major disaster - the suffocation of five coal-mine workmen - was caused by a fire at a fan on the surface. That record is the worst since 1945, when a series of fire disasters cost the lives of 79 miners. Except for these recent disasters, the coal mines have been almost free of fatalities from fires since those that occurred in 1942-45 brought forth new safety measures to protect mine workmen against fire hazards. The increase in fires in 1948 and 1949 raises the question as to whether there has been a falling off in fire prevention and fire safety practices. The reports on the fires of the past year indicate that in the larger and better-managed mines the danger to men from fires is given careful attention, but that the prevention of fires of electrical origin has not been mastered. In the smaller mines, fires from blasting with black blasting powder are commonplace but endanger few lives.

Table 6 lists the fires reported for 1949 and shows six in Illinois, five each in Colorado and Kentucky, four in Pennsylvania, three in Indiana, two in Washington and in West Virginia, and one each in Alabama, Tennessee, and Utah. The metal-mine fires recorded were two in Idaho, two in Minnesota, and one each in California, Michigan, New Mexico, and Wisconsin. A few more fires, reported in previous years, are still being controlled, and Bureau of Mines men were called to assist in this work; these fires are not included in this year's tabulation. Generally prompt action is now taken to extinguish or check underground fires to prevent the waste and delay that confronts those called on to take action after a fire has spread and approaches are cut off.

Surface fires that destroyed tipples, plants, shops, and other structures but did not affect the mine workings are not listed in table 6.

In 1949, eight metal-mine fires were reported, six of which were extinguished by direct attack with water or other extinguishing agents and two were sealed. In four of the fires loss and damage was small; in three the cost was moderate, but in the other the cost was heavy. Five of the fires were caused by arcing or overheating of electric wires or electrical equipment, two were caused by welding or cutting torches, and one by smoking.

The hazards indicated by the fires during the last 2 years are faulty electric equipment, installation, and upkeep; careless use of open flames, use of black blasting powder and dynamite in coal mines, neglect of old fires, and spontaneous combustion. One of the most frequent sources of coal-mine fires is arcing of trolley wires or bare power cables that contact machine frames or rails. So far, means of eliminating these sources of fire from coal mines have not been devised.

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TABLE 6. - Summary of mine fires, by States, 1949

State	Lighting used		Fatalities, by cause of ignition									
			Electricity		Open flame		Explosives		Unknown or miscellaneous		Total	
	Open	Closed	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires
Coal mines:												
Alabama	-	1	-	1	-	-	-	-	-	-	-	1
Colorado	-	5	-	1	-	-	-	-	-	4	-	5
Illinois	1	5	-	3	-	-	-	2	-	1	-	6
Indiana	2	1	-	1	-	-	-	2	-	-	-	3
Kentucky	4	1	-	2	-	-	-	3	-	-	-	5
Pennsylvania	1	3	4	2	-	-	-	-	-	2	4	4
Tennessee	-	1	-	-	-	-	-	-	-	1	-	1
Utah	-	1	-	1	-	-	-	-	-	-	-	1
Washington	1	1	-	-	-	-	-	-	-	2	-	2
West Virginia	-	2	-	1	-	-	-	-	-	1	-	2
Metal mines:												
California	-	1	-	-	-	1	-	-	-	-	-	1
Idaho	-	2	-	2	-	-	-	-	-	-	-	2
Michigan	-	1	-	1	-	-	-	-	-	-	-	1
Minnesota	-	2	-	1	-	1	-	-	-	-	-	2
New Mexico	1	-	-	-	-	1	-	-	-	-	-	1
Wisconsin	1	-	-	1	-	-	-	-	-	-	-	1
Total	11	27	4	17	-	3	-	7	-	11	4	38

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Table 7 lists the mine fires recorded since 1930, according to causes. It shows that before 1944 most of the fires were in open-light mines, whereas since that year most of them have been in closed-light mines. In recent years closed lights have been adopted in a large percentage of the total mines. The number of fires of electrical origin in 1948 and 1949 warns of the seriousness of the electrical hazard. The average of such fires for the last 6 years is 12.3, compared with an average of 6.9 for the 16 years 1929-44. More fires from explosives were reported for 1949 than for earlier years, but this may be because more thorough investigations were made. Under miscellaneous are included eight fires from spontaneous combustion.

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TABLE 7. - Summary of mine fires, by causes, fiscal years 1929-44 and calendar years 1944-49

Year	Lighting used			Fatalities, by cause of ignition									
				Electricity		Open lights		Explosives		Unknown or miscellaneous		Total	
	Open	Closed	Unknown	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires	Deaths	Fires
Fiscal years 1929-44	130	100	126	53	112	10	19	5	37	54	188	122	1/356
Average, 16 years...	8.1	6.3	7.9	3.3	6.9	.6	1.2	.3	2.3	3.4	11.8	7.7	22.3
1944.....	5	29	-	75	23	2	3	-	3	2	5	79	34 (10 metal)
1945.....	6	14	-	-	9	-	2	1	5	-	4	1	20 (4 metal)
1946.....	11	12	-	-	7	-	7	-	1	-	8	-	23 (4 metal)
1947.....	3	15	-	1	9	-	1	-	1	-	7	1	18 (3 metal)
1948.....	8	13	-	2	10	-	3	-	2	6	6	8	21 (5 metal)
1949.....	11	27	-	4	17	-	3	-	7	-	11	4	38 (8 metal)
6-year total.....	44	110	-	82	75	2	19	1	19	8	41	93	2/154
Average 6 years.....	7.3	18.3	-	13.7	12.5	.3	3.2	0.1	3.2	1.3	6.8	15.5	25.7

1/ Includes 55 metal-mine fires and 12 outcrop fires.
2/ Includes 34 metal-mine fires.

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